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Hydraulics, Lubrication and Maintenance Management

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Cable Safe System  
For  
Shuttle Cars

A.C.A.R.P  
Project C10026

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# 1. SUMMARY

The primary objective of this project was to improve safety and to reduce the costs associated with failures of trailing cables on shuttle cars. A summary <sup>(a)</sup> of related 'incidences' from the relevant authorities for the mines in NSW and Qld. shows that up to 51% of the problems may relate to inadequate cable tension.

These objectives were met through the development of a cable reel system offering:

1. An increase to the minimum tension when reeling-in while providing a reduction to the maximum tension that occurs during the pay-out process.
2. Improved visibility for the operator.
3. Improved cable laying.
4. Reduced friction at the sheaves.
5. Improved protection for the cable.

Systems are offered as a retrofit for existing fleets and there are twenty-two vehicles operating at seven mines fitted with a Cable-Safe hydraulic system together with various features as determined through this project. All are operating successfully <sup>(b)</sup> and in each case the total fleet is being progressively upgraded.

Two versions of a constant tension system (CT) were developed and prototypes were tested in above-ground conditions. Both systems performed to expectations but whereas the hydro-mechanical version is ready for under-ground evaluation, the computer-based system requires considerable investment to gain the necessary approvals.

Given the excellent performance of the simple Cable-Safe system, it is intended to continue monitoring and to introduce the more complex 'CT' system when the potential benefits become clearer. Applications for patents will be timed accordingly.

Information concerning this project has been disseminated through the presentation of a paper <sup>(c)</sup> to industry associations and to individual mines. In addition, an audit system <sup>(d)</sup> has been developed and is offered to all mines.

## 2. RECOMMENDATIONS

Based on success to date, Hyden will continue to recommend the use of the Cable-Safe system and to introduce the more complex hydraulic 'CT' system only if the potential advantages become more apparent. The current recommendations and suggested considerations include the following:

1. **Cable type:** Consider a change to a 35-mm cable. Although the catenary is negatively effected by a 20% weight increase, this is more than offset by a 40% increase to the rated tension ([http://www.au.pirelli.com/en\\_AU/cables](http://www.au.pirelli.com/en_AU/cables)).
2. **Vehicle brakes:** Typically, brakes apply a maximum brake pressure of 900-psi but approvals exist to use lower maximum pressures of 500-psi and 700-psi. A lower pressure is recommended to reduce the transient loads that occur while braking, particularly with the larger diameter reel.
3. **Boom Raise:** Operators with cars having a Voac piston motor have three options. Arrange for the cable to be paying-out while the boom is being raised, replace the motor with a gear type or modify the circuit to avoid back-pressure.
4. **Operator vision:** Modify the hungry boards and raise the seat <sup>©</sup>, where possible, to improve the operator's vision of the cable. Increase cable tension to the maximum through the use of a Cable-Safe valve and select an appropriate motor, sprockets and operating pressure.
5. **Archimedes:** Select a sprocket drive ratio to suite the drum width, cable diameter and the pitch of the Archimedes screw. Generally, the ratio will be between 1.1:1 and 1.2:1.
6. **Sheave Assembly <sup>©</sup>:**
  - (a) Modify the system so that the top plate protrudes the bottom plate by more than the cable diameter. This inhibits crushing against the rib.
  - (b) Reduce the protrusion of the bottom plate beyond the rollers to a minimum. This reduces the friction while back-spooling.
  - (c) Use deep grooved rollers. This minimizes friction between the cable and the lower plate.
7. **Cable reeling transmission:** Select an appropriate pump size, motor size and drive sprockets to suite the maximum vehicle speed plus a 40% factor to allow for cornering at full speed with the reel outermost. The traction box ratio, the grades encountered and whether the drive is AC or DC determines the maximum vehicle speed.

- 8. Operating Pressure:** A Cable-Safe system is recommended to permit the highest possible reel-in tension and pressures should be set to the maximum as limited by the cable tension <sup>(e)</sup>.
- 9. Operational comments:** Back-spooling should be minimized and low tram should be selected if the road condition is poor. The condition of the road from the 'boot' to the 'anchor' is the most critical.

# ACHIEVEMENTS AGAINST OBJECTIVES

The objectives identified at contract commencement were as follows:

## 1. Prime objectives:

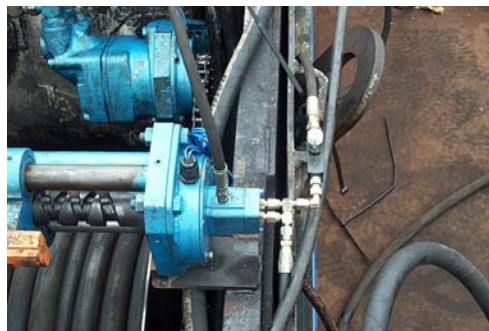
- a) Reduced cable failures and associated risks.
- b) Reduced cable handling and associated risks
- c) Reduced load at the cable reel, chain drives and cable guide devices.

Initially, it was anticipated that these objectives would be achieved through the development of a constant tension system, using a variable pump that may be retro-fitted to existing fleets. However, early in-depth studies <sup>(f)</sup> showed that neither the use of a variable pump nor a variable motor would provide a cost-effective solution, particularly given the tight space constraints. Accordingly, the contract was varied to develop a constant tension system using a 'LH' Cable-Safe system or a 'LHRC' system using a simple electronic logic to control system pressure.

Efforts were first directed towards obtaining control signals for pedal actuation, system pressure, Archimedes motion, motion of the cable reel motor and wheel speed with this last sensor presenting the greatest difficulty.

Fortunately, through this process it was realized that many of these sensors were not essential and that a very simple system was possible so that a hydro-mechanical logic became a realistic potential. However, at this stage the work against the more complex and more costly electronic system was very advanced and a decision was made to develop both systems in parallel.

Prototypes were constructed, fitted to the 15sc test vehicle, and subjected to proof-of-concept testing at the Myuna test track. Both the mechanical and the electronic systems performed to expectations and provided a near constant tension over the full travel.



The electronic 'CT' offered several advantages against its higher cost and higher level of complexity. It monitored the relative motion between the cable reel and Archimedes, provided a low cost means of controlling the speed at which the cable could be wound-in with the car stationary and controlled the amount of overrun that occurred during braking while the car was in the pay-out mode.

A comparison between the electronic CT-E, hydraulic CT-H, the LH Cable-Safe system and the standard is shown. A ratio of 1 for tension indicates that the system is capable of providing a reel torque that matches the acceleration of the vehicle due to cornering, bumps in the road or due to normal acceleration. Thus it can be seen that the standard system gives only 40-60% of the tension required, the 'LH system meets the requirements for a 35-mm cable and falls slightly short for the 25-mm cable and that both 'CT' systems provide considerable margin.

<b>FACTOR</b>	<b>CT-E</b>	<b>CT-H</b>	<b>LH</b>	<b>STD</b>
Tension/visibility - AC & 25-mm cable	1.3	1.3	<b>0.8</b>	<b>0.4</b>
Tension/visibility - AC & 35-mm cable	1.7	1.7	1.0	<b>0.5</b>
Tension/visibility - DC & 25-mm cable	1.4	1.4	<b>0.9</b>	<b>0.5</b>
Tension/visibility - DC & 35-mm cable	1.9	1.9	1.2	<b>0.6</b>
Archimedes motion sensor	Y	N	N	N
Controlled reel speed - car still	Y	Y	N	N
Reel overrun control	Y	N	N	N
Cable tidy - less over-wrapping	1.5	1.5	1.2	1

Notes:

- a) The motion sensor for the Archimedes is less critical with the introduction of the overfill-protection device.
- b) A controlled reel speed may now be developed for the 'LH' system.
- c) The benefit of inhibiting overrun of the reel is yet to be evaluated by industry.
- d) Reduced over-wrapping is an important factor.

## **2. Secondary objectives:**

A second objective was to perform a brief study of the cable management system (Archimedes), since poor performance in this area is believed to contribute to cable failures.

Studies revealed the following:

- a) A poor match existed between the width of the cable reel, the cable diameter and the pitch of the Archimedes screw. The number of wraps across the reel varied between 12 and 13 against 11 turns of the Archimedes so that the sprocket ratio should be between 1.1 and 1.2:1 against the normal 1:1 ratio.
- b) Under some transient conditions, approximately 60% of the total torque from the motor maybe absorbed at the Archimedes. In addition to proper timing between the reel and screw, the relative position of the large roller, hairpin and reel is important so that the hairpin is not 'bending' the cable between the roller and reel. Generally this favors the use of the shortest possible hairpin.

- c) For reliability, the Archimedes is best positioned away from the cable exit so that contamination from the cable does not fall directly onto the screw.
- d) The rollers should be deep grooved to minimize the friction between the cable and bottom plate. The side clearance between the rollers and plates should be a minimum to prevent 'wedging' of the cable.
- e) For maximum cable protection, the top plate should protrude the bottom plate by at least the cable diameter.
- f) The protrusion of the bottom plate beyond the large roller should be minimized to reduce friction during the pay-out mode.
- g) Consideration should be given to handling spare cable in a figure '8' configuration to inhibit twisting while reeling-on.

### 3. Other:

3.1 Bumps: The track used for the 'Myuna' tests was considered satisfactory. Sleepers were used to simulate a single bump in close proximity to the anchor.



3.2 Cornering tests: The inside turning radius is about 2.5m and the outside radius is about 5.5m so that the speed ratio is about 2.2:1. Tests on the DC car at Myuna indicated a wheel speed of 3.57 rpm on a flat road without cornering with wheel speeds of 4.65 rpm and 2.22 rpm for the outside and inside wheels respectively while cornering. Thus for a top speed of 6-kph, one would expect the relative speeds to be 7.8-kph and 3.73-kph with a speed average of 5.78-kph.

Thus the flow demand for the pump needs to be increased by a factor of 1.3 to handle full speed cornering with a near empty reel. For a safety factor, we propose a factor of 1.4.

3.3 Anchor tests: The anchor design is not overly relevant and the only significance of the anchor is that it represents the position at which the system changes from low tension reeling-in to high tension paying-out. Thus any overwrapping or looping that occurs during reeling-in will cause failure during the pay-out process.

3.4 Maximum system pressure: The maximum system pressure depends on the system design standard, 'LH' or 'CT' in addition to the ratings of the cable, the motor used and sprocket ratio's as shown at appendix 'd'.

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